Fixed and Variable Frequency Crystal Oscillators

he hearts of many simple pieces of test equipment and transmitters are crystalcontrolled oscillators. Quartz crystals provide stable frequency control for many circuit sections in such equipment. Crystals

are used extensively in most receivers, where they serve in heterodyne oscillators and BFOs (beat frequency oscillators).

Some receivers contain crystals for use in calibrators that provide accurate markers every 10 or 100 kHz across the tuning range of the receiver. This is an aid for ensuring correct dial calibration, especially when operating vintage receivers.

Learning how to make crystals oscillate is important for the experimenter or those who need to repair a piece of equipment. Knowledge about how to shift the frequency of a crystal is beneficial, too. This is especially true of crystals that have aged and no longer operate on their marked frequencies. This article provides basic information on how to build and maintain "rock-bound" oscillators, as they are often called.

Crystals come in all sizes and shapes today, but irrespective of the physical format, the innards are somewhat standard. It is the metal or plastic case in which they are housed that makes them look different.

Two basic types of crystals are marketed today. One is known as a "fundamental" crystal, which means it operates on its natural frequency, such as 7 MHz. The other type is called an "overtone" crystal. It is cut for a particular frequency, such as 7 MHz, but is made to oscillate at an odd harmonic (3rd. 5th, 7th overtones, etc.) of the fundamental crystal frequency. The 3rd overtone for a 7 MHz. In practice, the overtone is seldom related precisely to the fundamental frequency, but it is very close.

Types of Crystals

MHz crystal would be approximately 21

■ Basic Oscillator Circuits

Figure 1 shows four types of crystal oscillators. The circuit at A is a standard Pierce oscillator. It does not require a tuned (resonant) circuit at the output of the JFET device, Q1. Y1 oscillates on its fundamental frequency. Capacitors C1 and C2 provide the feedback power (output power fed back to the input circuit) needed to make the crystal vibrate at its marked frequency. Suggested reactance values are listed for C1 and C2.

Simple equations for determining the actual capacitance value when the reactance (XC) and frequency are known are given in The ARRL Electronics Data Book and The ARRL Handbook. Typical values for C1 and C2, respectively, for operation between 1 and 15 MHz are 39 pF and 69 pF, based on

Figure 1 -Practical examples of simple crystalcontrolled oscillators, A Pierce oscillator is shown at A. A Colpitts oscillator appears at B, a tuned collector oscillator at C, and an overtone oscillator at D. MPF102 fieldeffect transistors may be substituted for the 2N4416 devices shown. A 2N4400, 2N4401. or 2N3904 can be used in place of a 2N2222. All

resistors are 1/4-

W carbon types.

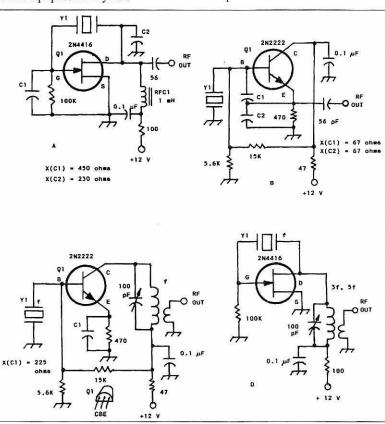
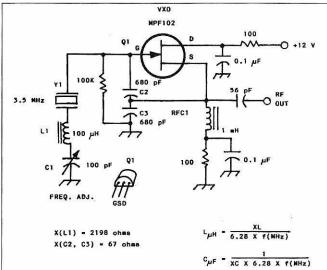


Figure 2 -Circuit example of a VXO. The crystal frequency can be varied by adjustment of C1 (see text). The greater the L1 inductance the wider the frequency change for YI. A maximum capacitance of 100 pF is suggested for C1. An RFC1 value of 100 microhenries is suggested for operation from 2 to 4 MHz. A 50-microhenry RF choke may be used from 4 to 10 MHz, and a 22-microhenry RF choke is suitable for operation from 10 through 20 MHz. Miniature RF chokes offer good performance in this circuit.



10-MHz operation. These values increase as the operating frequency is lowered. A 1-millihenry RF choke is suitable for RFC1 over the above range of frequencies.

Figure 1B shows a standard Colpitts oscillator. It also operates without an output tuned circuit. C1 and C2 are the feedback capacitors. Their XC values are listed. For operation at 3.5 MHz an XC of 67 ohms computes to 680 pF.

The circuit at Figure 1-C is also a fundamental oscillator. It contains a tunable output circuit that is set for resonance at the crystal frequency. The feedback is controlled by C1. With an XC of 225 ohms we would use a 100-pF capacitor.

It should be noted that bipolar transistors (BJTs) and field-effect transistors (JFETs) can be used in any of the circuits shown, provided proper dc biasing (base or gate resistors, as shown) is used.

Overtone Operation

Figure 1-D illustrates how an overtone oscillator is configured. Feedback capacitors are not required because there is sufficient capacitive coupling within Q1 to provide feedback at typical overtone frequencies (generally above 20 MHz). Tuned circuit T1 is adjusted for resonance near the desired overtone in order to make oscillation begin and sustain.

Harmonic operation at various multiples of the crystal frequency (i.e., 14-MHz output from a 7-MHz crystal) can be obtained with the circuit of Figure 1C by resonating the output tuned circuit at 14 MHz and using 0.01 μF at C1.

Shifting the Crystal Frequency

Figure 2 shows how to move the crystal frequency in a circuit that is called a VXO (variable reactance oscillator). L1 and C1 are used in series with the grounded end of the crystal. As C1 is adjusted, the output frequency of the oscillator changes. This is called "pulling" or "rubbering" a crystal.

In most VXO circuits the output frequency starts slightly above the marked frequency of the crystal (C1 at minimum capacitance) and moves lower as the C1 capacitance is increased. Typical frequency swings are 3 kHz at 3.5 MHz, 8 kHz at 7 MHz and 15 kHz at 14 MHz with the reactance values listed. If L1 is eliminated the crystal can still be rubbered, but only a small change will occur with only C1 in the circuit. This circuit is ideal for experimental purposes.

Best VXO performance will occur when using plated AT-cut crystals in the larger HC6/U style of holder. The old WW-II sur-

plus FT-243 crystals can be made to work, but they do not allow much frequency change, and they may not oscillate if the internal electrodes are oxidized.

Some crystal-controlled oscillators in commercial radios can be changed to VXOs by adding a trimmer capacitor and a small inductance. This is a useful modification when the crystal or other components in the circuit have aged to the point where the oscillator can no longer be netted to the desired frequency by means of the related trimmers. Crystal-controlled CB transmitters and amateur VHF transceivers can be brought back on frequency by adopting the VXO principle rather than buying an expensive replacement crystal. VXOs are useful for frequency control in simple amateur CW transmitters, since they are more stable than many home-made VFOs.

Wiring Tips

Short, direct leads are advisable in all RF

circuits, and this includes oscillators. In the interest of optimum frequency stability it is prudent to use NP0 ceramic, silver mica, or polystyrene capacitors in the feedback part of the circuit. Additional stability is assured when the oscillator operating voltage is regulated.





